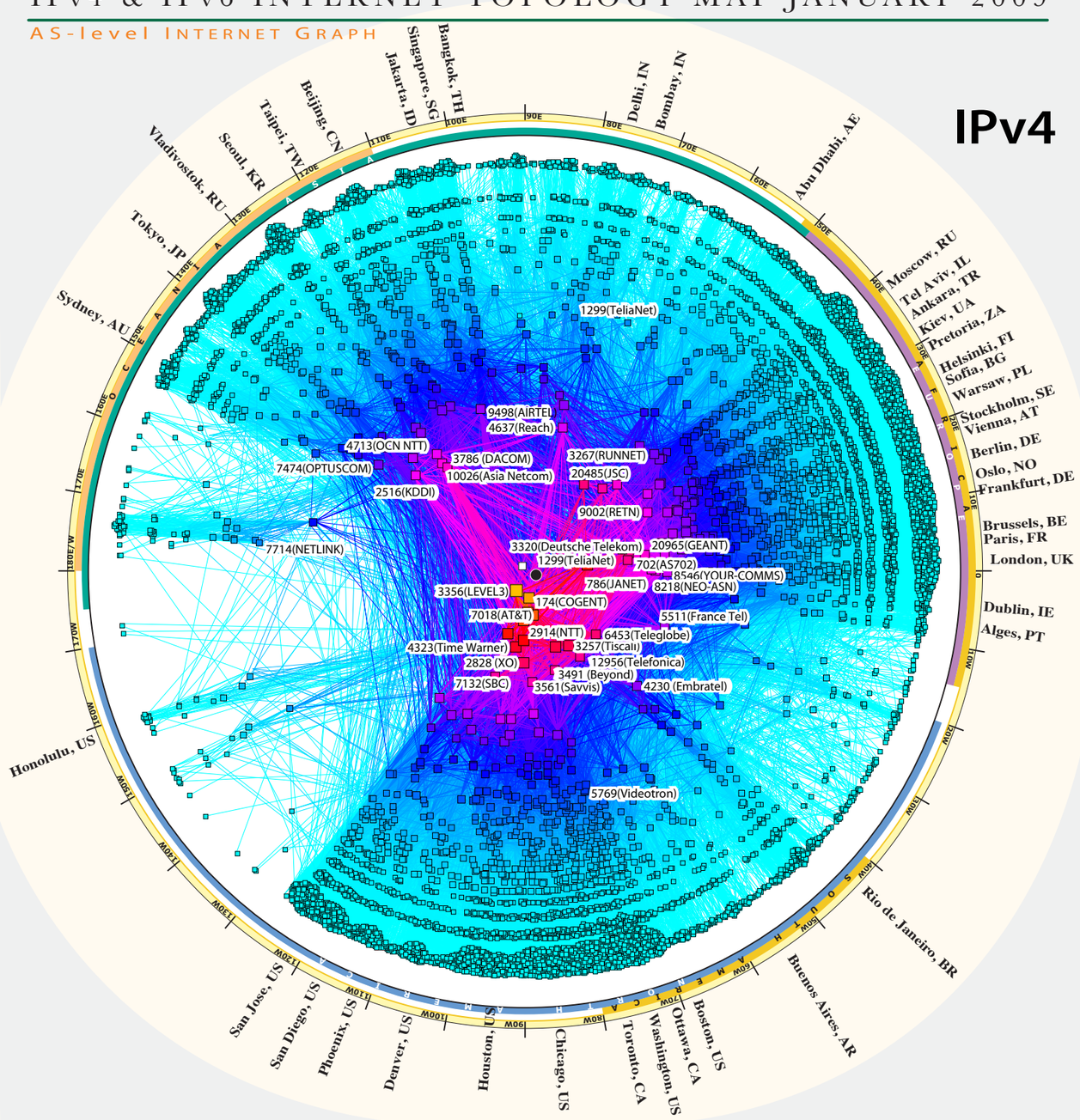
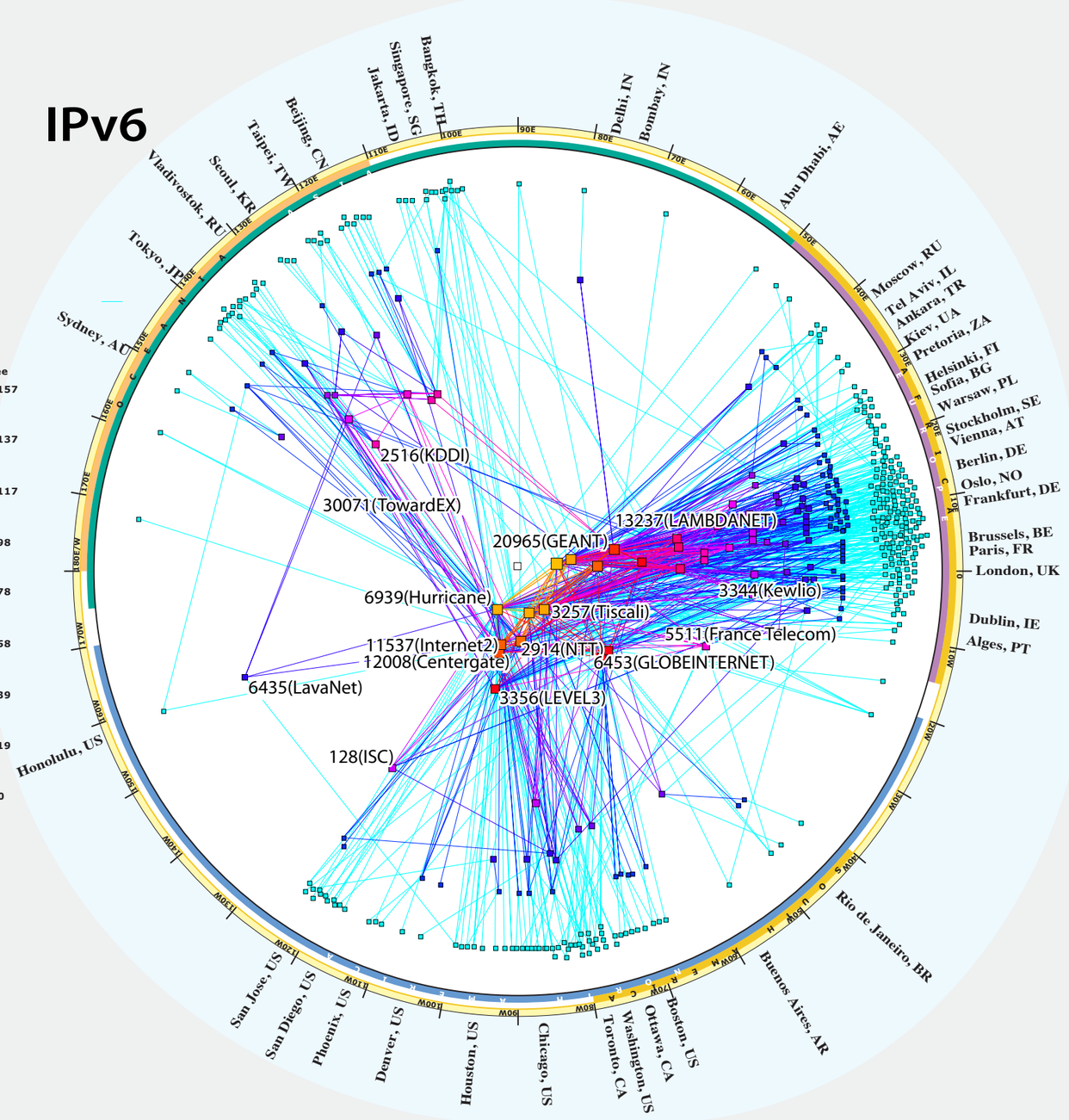
IPv4 & IPv6 INTERNET TOPOLOGY MAP JANUARY 2009

AS-level INTERNET GRAPH



Peering: OutDegree

1845	157
1614	137
1383	117
1153	98
922	78
691	58
461	39
230	19
0	0



	Dates	Number of IP address	Number of IP links	Number of ASes	Number of ASlinks
IPv4	Jan. 2nd-17th, 2008	4,853,991	5,682,419	17,791	50,333
IPv6	Jan. 1st-8th, 2008	4,752	17,036	489	1,904

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ARK HOSTS . AARNet . APAN . ARIN . ASTI Institute . CANET . CENIC . CNRST . ELTENET . FunkFeuer . HEANet . Iowa State University . KREONet2 . Purdue University . RNP . TKK . Universitat Leipzig . Universitat Politecnica . University of Cambridge . University of Hawaii . University of Waikato

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This visualization represents macroscopic snapshots of IPv4 and IPv6 Internet topology samples captured in January 2009. The plotting method illustrates both the extensive geographical scope as well as rich interconnectivity of nodes participating in the global Internet routing sytem.

For the IPv4 map, CAIDA collected data from 33 monitors located in 30 countries on 5 continents. Coordinated by our active measurement infrastructure, Archipelago (Ark[1]), the monitors probed paths toward 7.4 million /24 networks that cover 95% of the routable prefixes seen in the Route Views[2] Border Gateway Protocol (BGP) routing tables on 1 January 2009.

For the IPv6 map, CAIDA collected data from 6 Ark monitors located in 4 countries on 2 continents. This subset of monitors probed paths toward 1,491 prefixes which represent 88.9% of the globally routed IPv6 prefixes seen in Route Views BGP tables on 1 January 2009.

[1] Ark http://www.caida.org/projects/ark
[2] Route Views http://www/routeviews.org

We aggregate this IP-level data to construct IPv4 and IPv6 Internet connectivity graphs at the Autonomous System (AS) level. Each AS approximately corresponds to an Internet Service Provider (ISP). We map each observed IP address to the AS responsible for routing traffic to it, i.e., to the origin (end-of-path) AS for the IP prefix representing the best match of this address in the BGP routing tables. For the IPv4 graph, we used the BGP IPv4 routing table provided by Route Views. For the IPv6 graph, we used the IPv6 routing table collected by RIPE NCC[3].

$$\text{radius} = 1 - \log\left(\frac{\text{outdegree(AS)} + 1}{\text{maximum.outdegree} + 1}\right)$$

$$\text{angle} = \left(\text{longitude of the AS's BGP prefixes in netacq}\right)$$

The position of each AS node is plotted in polar coordinates (radius, angle), position being calculated as follows:

[3] Ripe NCC http://www.ripe.net

The outdegree of an AS node is the number of next-hop ASes that we observed accepting our probe traffic as it left this AS. The link color reflects outdegree value, from lowest (blue) to highest (yellow). Toward the center of the graph we have manually labeled some of the highest outdegree ASes with their associated ISPs.

To determine the longitude of an AS, we used the IPv4 BGP table from Route Views to find a set of announced IPv4 prefixes for each AS. We subdivided prefixes into the smallest prefixes that Digital Envoy's NetAcuity[4] (R) mapped to a single geographic location in January 2009. We then calculated the AS angle coordinate from the weighted average (by number of IP addresses in each mapped prefix) of the longitude coordinates of all such subdivided prefixes. NetAcuity currently only supports IPv4 mapping, so we use the IPv4-derived locations for ASes in both graphs.

[4] Digital Envoy http://www.digitalemvoy.net/

Calculating AS coordinates as described above results in a large number of overlapping nodes (hundreds in the case of the IPv4 graph) which distort the graph's edge. To better visualize so many ASes at the edge, we refined our node placement algorithm to spread out overlapping nodes. This modification creates bulges in the outermost ring of the AS-core, corresponding to longitudes with substantial Internet infrastructure deployment, which also correlates with populous regions of the globe.

The IPv6 graph grew from 486 AS nodes in January 2008 to 515 nodes in January 2009. Over the same period we saw an increase in the number of IPv4 ASes from 18K to almost 23K. Whether these are the result of new AS allocations or changing to our measurement methodology is not clear. Compared with the AS-core graph of January 2008, we observed a westward shift in the position of ISP TelstraClear due to its increased presence (per NetAcuity's mapping) in Australia.